Learn Together: Collaborative Distance Learning in Immersive Virtual Reality

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ABSTRACT
UPDATED—**26 July 2018**. Distance learning has increased the reach of quality education to more individuals, but at the risk of a loss of a sense of presence and collaboration with peers and instructors. Learn Together is an attempt to address these issues by offering an immersive virtual environment with a selection of tools to facilitate collaborative learning using virtual reality technology.

Author Keywords
virtual reality; collaboration; education; social learning

ACM Classification Keywords
• **Applied computing~Collaborative learning**

• *Applied computing~Digital libraries and archives*

• **Software and its engineering~Virtual worlds training simulations**

• *Information systems~Multimedia streaming*

INTRODUCTION

Online learning technology is a powerful tool in the educational toolbox. For a well structured online program students need only a computer and Internet connectivity to access a high quality education. However "learning is largely driven by exchange with peers" [1], and since online students are physically distant from their classmates and instructors they can feel isolated and have reduced motivation, leading to increased dropout rates [2].

Many technologies have been developed to address the limitations in distance learning such as classroom web forums, collaborative wikis, voice and video chat, and social networking platforms.

Virtual reality has been shown to provide a sense of presence similar to being physically in person [3] and it has been shown to be beneficial in education by providing a "strong sense of collaboration with others" [4].

While virtual reality technology has been available for decades, recent advances in the technology have greatly increased its reach and accessibility, thus increasing the utility of this technology for distance learning.

This paper introduces "Learn Together", a distance-learning solution that implements a multi-user virtual classroom platform with a set of collaborative tools. It addresses four concerns related to distance learning:

- **Presence:** Participants can move freely within the virtual environment with a sense that they are physically there.
- **Collaboration:** Participants can see and interact with other participants by speaking, interacting on virtual whiteboards, and displaying visual content such as video or slideshow presentations through a streaming desktop implementation.
- **Educational Content:** Educational content can be presented by individual participants by sharing their desktops, or by interacting with embedded web browser panels preconfigured with course reference materials.
- **Retention and Reference:** Participants can access their desktop note taking software within the virtual environment, or may record the entire virtual reality session for later playback within virtual reality.

Taxonomy of Virtual Reality Content

Presentation of educational content in immersive virtual reality may take different forms, but typically it can be categorized in three different ways:

- **Static video recording**: 360-degree spherical video recording capturing every direction from a central viewpoint. Since these are video recordings the participant is unable to interact with the scene.
- **Virtual classroom**: A virtual environment which simulates a traditional classroom through the use of whiteboards and 2d video projections. Virtual

classrooms may be collaborative in the sense that multiple participants may connect to the environment and interact with each other. Virtual classroom content can typically be presented on traditional video displays without virtual reality hardware.

- **Native content experience**: A native virtual reality experience consists of content developed specifically for use with virtual reality hardware, such as virtual field trips exploring ancient ruins or interactive medical training on virtual cadavers.

RELATED WORK

Trials of the Acropolis is an interactive native experience virtual reality application demonstrating that the technology can be used to improve student engagement during the learning process [5].

Susan Jang et. al. demonstrated that the direct manipulation of anatomical structures using virtual reality technology improved learning outcomes over participants not using virtual reality technology [6].

Collaborative Learning Environment with Virtual Reality (CLEV-R) is a virtual classroom environment demonstrating the utility of using virtual environments in education [7]. CLEV-R provides education-focused tools such as note taking and text chat. The platform was found to be an effective way with others. 95% of participants in a study using CLEV-R had a "strong sense of collaboration with others" [8].

THE SOLUTION

Learn Together is implemented as as a virtual classroom. It is a desktop application that runs in either server mode or client mode. Each participant is represented within the environment with a virtual avatar. The avatar consists of a head positioned where the participant's VR head mounted display is located, and spheres to represent the location of the participant's controllers. Participants may freely join or exit the session at any time.

Figure 1. Participant avatar

Within the virtual environment are three virtual classroom areas. The largest of these has a large projection screen and two virtual whiteboards. Each of the smaller classrooms consist of a smaller projection screen and one whiteboard.

Participant Interaction

In addition to the avatar representations, there are two ways participants can interact with each other in the environment:

Voice Chat

The application has a voice chat capability. Any participant may speak at any time and all other participants will hear their speech.

This allows participants to discuss content in the classroom, or present information.

Emoji State

Emoji are pictographic characters popularized by text messaging and are typically used to express basic information, activities and emotion. By pressing two buttons on a controller simultaneously an emoji selection wheel appears surrounding the participant's controller. When an emoji is touched and the buttons are released the selected emoji appears above the person's avatar's head.

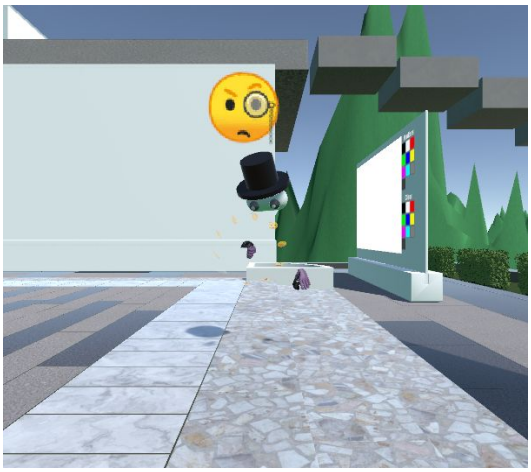

Figure 2. Emoji States

Since the emoji appears above the participant's head it is very noticeable from a distance, especially if there is a large crowd of participants.

This capability can for example be used to silently indicate when a participant has a question, or disagrees with a point made during a presentation.

Participant Tools

There are three tools within the environment that each participant may independently control:

Virtual Desktop

The virtual desktop tool enables participants to access their desktops without leaving the virtual environment. Participants can interact with the virtual desktop by pointing the controller at the screen to move the cursor, activate left and right mouse buttons, and scroll with the controller touchpad or thumbstick.

Figure 3. Virtual Desktop

When combined with a keyboard the virtual desktops can be used to take notes or search the Internet for reference material.

Since the virtual desktop is an accurate stream of the participant's desktop, anything that can be accessed on the computer is available from within the virtual environment.

The virtual desktop can operate in two modes. In the default mode only the local user can see the desktop. In remote streaming mode all participants can see the virtual desktop.

When the virtual desktop tool is operating in streaming mode a window hovers in front of the participant's avatar displaying the participant's desktop. This can be used to show documents, websites, slideshow presentations, videos, or any other content that can be accessed from the participant's desktop.

External Camera

The external camera can be positioned anywhere within the virtual environment. If it is activated the view on the desktop window changes. Instead of duplicating what the participant sees through the VR display, it displays the perspective of the camera.

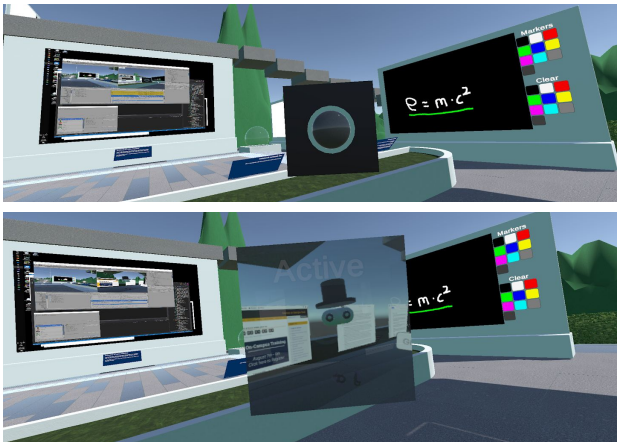

Figure 4. External Camera Disabled and Enabled

This tool is typically used to record video content of the virtual environment for playback on standard video displays. For example, a VR lecture could be recorded and later shared on a traditional video broadcasting platform. Many screenshots in this paper were taken by the external camera tool.

VR Session Recorder

The VR Recorder records all activity in the session for later playback. This includes the movements, speech, and emoji states of all participants, all interaction on whiteboards, and streamed desktop video. Unlike a static video recording, the VR Recorder enables users to move about the recorded session freely in virtual reality as if they were there live when it was originally recorded.

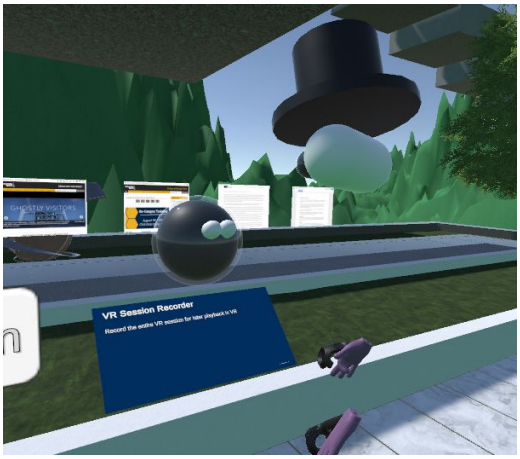

Figure 5. VR Session Recorder

Similar to the External Camera tool the VR Recorder can be used to record VR presentations, or to record meetings for group projects.

On a technical level this is accomplished in two stages:

1. When the recorder is first activated, the current state of the session is recorded. This includes the list and current state of participants, and the list and current state of all environment tools. Each of these objects has a unique ID number which is used to correlate network updates to specific environment objects. Each object also has a position and rotation within the virtual environment. This state information is stored in the same format as the network packets that were used to initially instantiate these objects within the environment.
2. All inbound network packets are saved with timestamps, where time==0 being the start of the recording.

Currently the VR Session Recorder is only available on client connections.

Playback of recorded content can be done either when the application is not connected to a server, or when the application is running in server mode. In either case the playback process is similar.

1. Each recorded packet is played back at the correct time based on the recorded timestamp and passed to the network client code within the application as if the packet actually came from a remote server.
2. If the playback is on a server, each of these packets is also broadcasted to all connected clients.

Environment Tools

Within the environment there is a selection of interactive tools.

Whiteboards

Each virtual classroom area has at least one whiteboard. Each whiteboard is synchronized so that all participants may interact collaboratively on the surface. There is a selection of different colors that may be used for drawing or clearing the board.

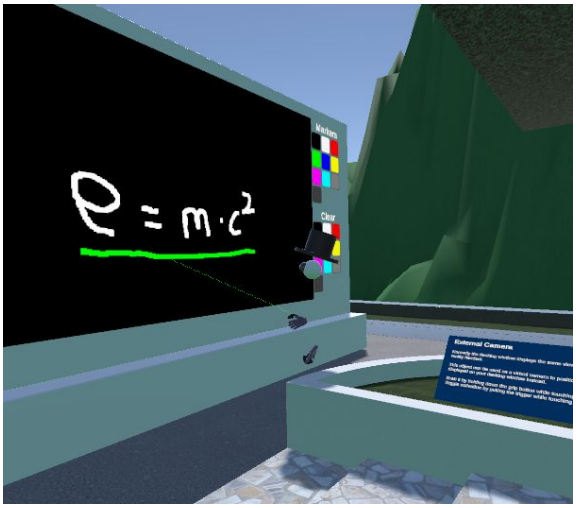

Figure 6. Whiteboard

There are two operations available on a whiteboard:

- Draw by pointing the controller at the whiteboard and holding down the trigger. The color is determined by the selected marker color.
- Clear the whiteboard to any available color by clicking the trigger on a clear color button.

Projection Screens

Each projection screen is located in a prominent position within the virtual classrooms. If a participant has the virtual desktop tool and streaming mode enabled and activates a projection screen then the participant's desktop will be displayed on the projection screen. This enables participants to present information from their desktops to a large group.

Figure 7. Projection Screen

These projection screens mirror the capability of the virtual desktop tool. Therefore any content available on the participant's desktop can be displayed on a projection screen.

TESTING

To test the effectiveness of the solution two tests were conducted:

Test 1: Training

Methodology

A short application tour and tutorial was recorded with the VR Session Recorder. This tutorial covered the all the tools within the application. Two participants then watched the tutorial from within the virtual environment: Participant A and Participant B.

Participant A has extensive experience with virtual reality technology and plays video games. Participant B has limited experience with virtual reality technology and does not play video games.

After watching the recorded VR session within the environment the participants were asked to perform tasks to demonstrate they understood the tutorial.

Results

Each participant was able to demonstrate that they learned and understood the material by using the whiteboard, activating the streaming desktop, setting an emoji state, and activating the streaming virtual desktop.

Limitations

The training tests only consisted of training how to use the application itself. To fully test the effectiveness of using this tool for training we would need to produce additional training materials in other domains, record the presentations in both VR and 2d video, play them back within the virtual environment for one subgroup of study participants and as 2d videos for another subgroup of study participants, and then evaluate their retention and understanding of the material.

After the training test Participant A commented that he was distracted by the virtual environment itself and found it difficult to focus on the learning material.

As this test was only performed with two participants it would be difficult to extrapolate and generalize the results on a larger scale. Additional testing with many different participants would be necessary to gauge the effectiveness of this tool.

Test 2: Collaboration

Methodology

A live online collaboration session was started with two participants. The participants were about 450 miles (725 km) apart. They discussed current and planned future projects, interacted on a whiteboard, looked up information in a web browser using the virtual desktop, and shared video content using a projection screen.

Results

The participants were able to share information and agreed the collaboration session was a success.

Limitations

The streaming virtual desktop framerate was noticeably low and was a distraction when streaming video content. Due to the limited time for development individual frames are encoded as images in WebP format rather than producing a properly encoded video stream. Streaming desktop packets are sent reliably over the Internet so for the long distance test there was significant latency since all packets were replayed.

The streaming virtual desktop functionality also does not stream the audio at this time. It only streams video.

As there were only two participants during the test it would be difficult to extrapolate how larger teams or groups would benefit. Further tests should be conducted with larger groups of participants.

CONCLUSION

For virtual reality to be useful in education it is important to identify how the technology can augment education rather than be tacked on as a novelty providing no concrete improvements in educational outcomes. One area that was identified as an ongoing challenge in education is the lack of direct interaction with peers and instructors in distance learning programs. Virtual reality technology, with its ability to create a sense of presence, immersion, and interactivity is a strong candidate to address this challenge.

Preliminary tests with Learn Together demonstrate virtual reality technology can be an effective tool for both training

and collaboration. Learn Together demonstrates that providing a virtual environment with multiple collaborative tools, access to educational content, recording and playback capabilities can provide positive learning outcomes.

Virtual reality technology is a rapidly advancing field. While the technology is still relatively expensive and cumbersome to use today it is expected that costs will continue to drop and hardware will become more compact and accessible. These trends will lead to wider availability of the technology and increase its viability as a pedagogical tool.

FUTURE WORK

Learn Together would be greatly enhanced by the inclusion of native experience content that could be loaded into the environment at runtime. This content would be designed to fulfill particular learning objectives. For example, allowing the scene to be changed from a classroom setting to an ancient settlement for collaborative exploration, or introducing interactive elements such as virtual cadavers for medical training.

The VR Session Recorder was added the last few days of the project and has quickly shown promise as a useful and powerful capability. Two tutorial training sessions were recorded and later played back to teach participants how to use the application, demonstrating the potential for Learn Together to be used as a tool for creating VR content. Further investigation in recording both educational content and collaborative VR sessions is warranted.

Combining runtime native experience content with the VR Session Recorder capability would make Learn Together into a rich platform for immersive collaborative learning.

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